Models of Acoustic Wave Scattering at 0.2-10 kHz from Turbulence in Shallow Water

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LONG-TERM GOALS

Long term goals are to better understand the physics of acoustic wave propagation in turbulence. Long-term goals are to develop mathematical model of acoustic wave scattering in turbulence, observe acoustic wave scattering (attenuation) in turbulence, and compare model with observation. This scheme is also extended to internal wave. All the mechanisms involved in the process of scattering and attenuation will be observed and compared with theory.

OBJECTIVES

The scientific and technological objectives are to develop a shallow ocean model assimilated with acoustic data. Also other objectives are to develop acoustic tomography to image the current velocity and turbulence in 3D space. The other objectives are to image acoustic wave scattering and attenuation. The objectives are to apply the numerical inverse methods to locate the trace of a submarine, manned and unmanned submersibles, and torpedo.

APPROACH

1. Develop shallow ocean model with data assimilation of tide gages, and acoustic data in real time.[Data assimilation model to be built as fund become available.]

2. Develop theoretical and numerical models of acoustic wave propagation in turbulent current.

3. Extract the turbulent structure from the archived (Kanmon Strait) data of average current and free stream turbulence inversely using the theoretical and numerical models of (2). The complete Kanmon Strait data were presented to the author by Dr. Arata Kaneko.

4. Compare the turbulent structure determined from data with the theoretical prediction.

5. Extract the acoustic wave attenuation and scattering from the Kanmon Strait data using tomography technique.

6. Repeat step 1 to 5 for internal wave when the tasks for turbulence will have been finished.

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14. ABSTRACT **Long term goals are to better understand the physics of acoustic wave propagation in turbulence. Long-term goals are to develop mathematical model of acoustic wave scattering in turbulence, observe acoustic wave scattering (attenuation) in turbulence, and compare model with observation. This scheme is also extended to internal wave. All the mechanisms involved in the process of scattering and attenuation will be observed and compared with theory.**						
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7. Dr. Yamamoto will take over all tasks 1 to 5. Dr. Mohsen Badiey will supply his tomography data to PI. Also, Robert Field of NRL-SSC will provide his acoustic wave transmission data through turbulence and internal wave. The PI and Altan Turgut will collaborate in the work of Ship noise propagation. The PI's analytical wave turbulence interaction will be used on Turgut data for the influence of turbulence on the Noise propagation. The experimental data will be compared with the theoretical and numerical models of acoustic wave propagation through turbulence.

WORK COMPLETED

Model of Acoustic Wave Propagation, Scattering and Attenuation in Turbulence
An analytical solution for acoustic wave scattering in turbulence (or internal wave) was derived.

Accurate Prediction of Oceanography by Data Assimilation [for Data Assimilation funding are being requested]

The locations of eight acoustic source-receiver pairs are given by solid dots in Figure 1. The number of acoustic pair starts from the west end on the north shore and turn clockwise. The area of tomography coverage is 1500 m wide x 2500 m. Three predictions of current field are compared in Figure 1. The red arrows are from ADCP. The black arrows are from acoustic tomography. White arrows are prediction by Princeton Ocean Model (POM) with kalman filter assimilation with a tide gage and selected acoustic transmission data from tomography rays. The assimilated POM is the most accurate.

At this phase of tidal current, the maximum current (~4 m/s) runs against the Northern shore while flow separation and a large counter crock wise eddy (~1 m/s) occupies the space between the midway and Southern shore. It is observed that acoustic wave attenuate below noise level when it travel (K1 to K5) through a high velocity current (~4 m/s) as shown in Figure 2. Attenuation is small for acoustic wave propagates through a large eddy (K8 to K5) with low current velocity (~1 m/s) as shown in Figure 3. These experimental facts are all predicted well by the theoretical model.

It is accomplished that the tidal current produces free stream turbulence proportional to the square of current velocity in shallow waters like Kanmon Strait. Where there is a high current there is strong turbulence and acoustic wave scatter off its energy strongly and attenuate strongly. On the other hand, where there is a low current, there is low turbulence energy. Acoustic wave hardly scatters its energy and propagates without loosing energy much.

IMPACT/APPLICATIONS

Theoretical means to accurately predict the behavior of free stream turbulence has been established and being validated by At Sea experiment. This method can be applied to locate submarine after careful submarine location experiments will have been done to verify the theoretical models.

TRANSITIONS

A potential future transition applies to the theoretical model to determine the behavior of free stream turbulence leading to location of submarines.

RELATED PROJECTS

Mohsen Badiey, Acoustic tomography using vector sensors.

Robert Fields, Acoustic wave propagation in Shallow Waters.

Altan Tugut, Use of ship noise for characterizing bottom sediments.

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Turgut, A. and Yamamoto, T., In-Situ Measurements of Velocity Dispersion and Attenuation in New Jersey Shelf Sediments: Journal of Acoustical Society of America, Extended Abstract [IN PRESS]

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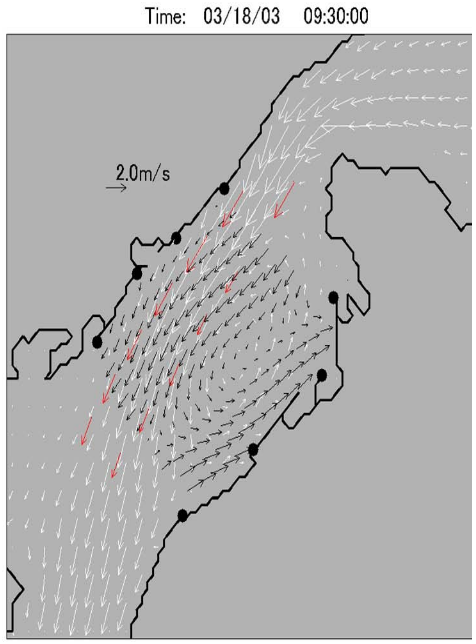

Figure 1. The red arrows are from ADCP. The black arrows are from acoustic tomography. White arrows are prediction by Princeton Ocean Model (POM) with kalman filter assimilation with a tide gage and selected acoustic transmission data.

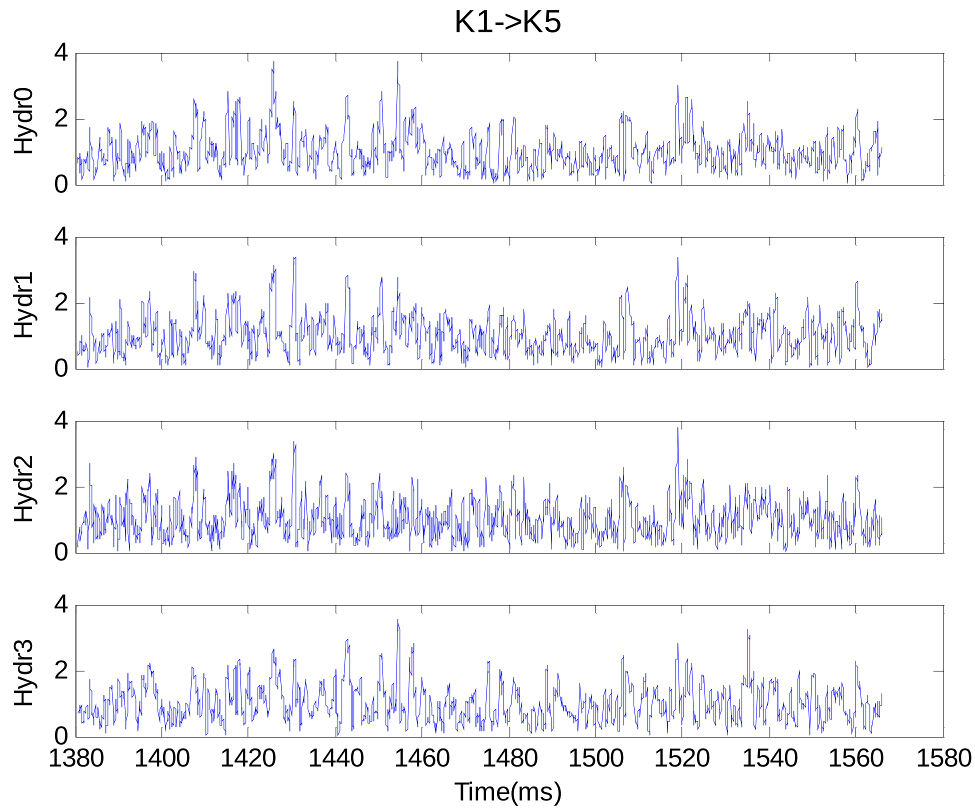

Figure 2. Received correlation wave form. M-sequence length is 1023. Signal propagates from station K1 to K5 range 2300 m. K1-K5 path goes through a very strong tidal current. Due to the strong current (~4 m/s), strong turbulence is generated. Thus, acoustic wave scatter strongly and attenuate strongly. Signal is buried under noise and can not be detected.

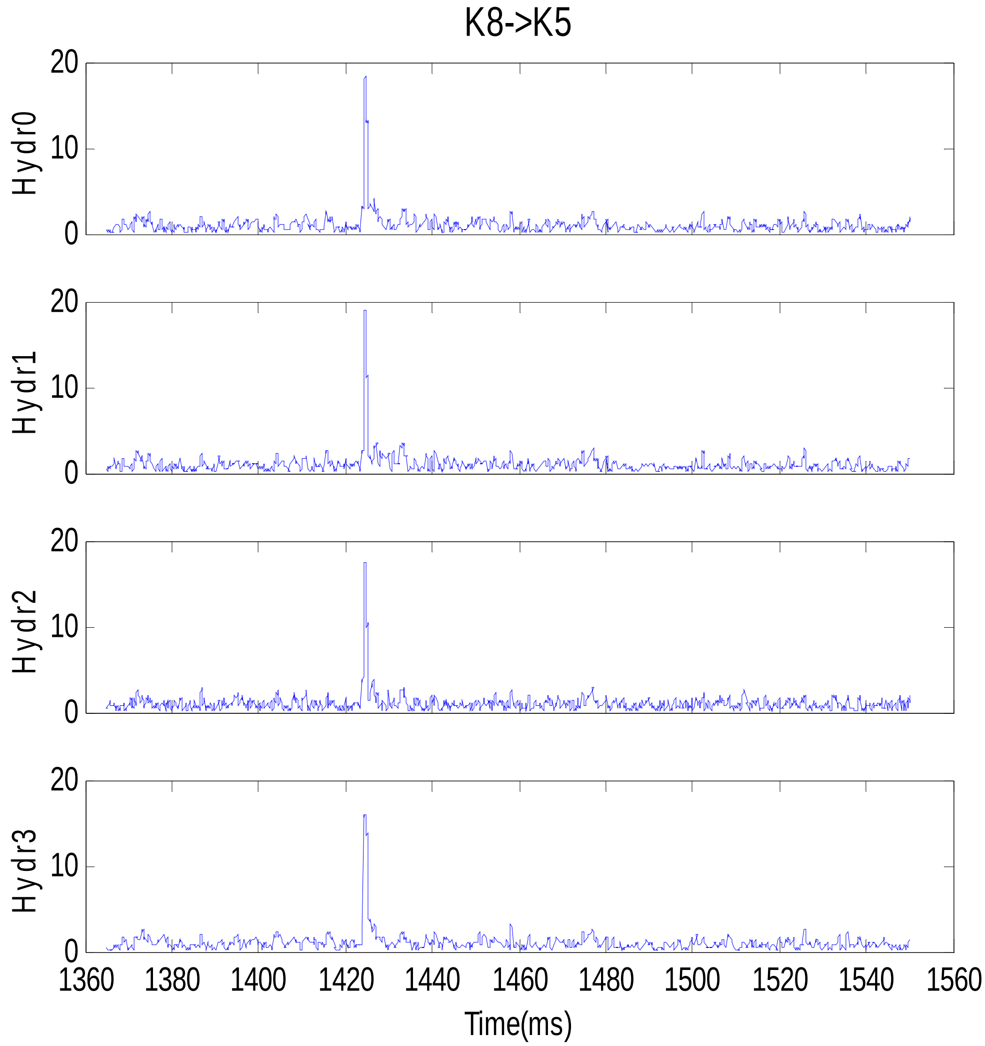

Figure 3. Received Correlation Wave Form for 1023 digits M sequence signal for signal transmission from K8 to K5, 2300 m. As can be seen in Figure 1, the path K8-K5 is in the slowly moving eddy (~1 m/s). This is why K8-K5 has very high S/N = 18. The analytical model predicts this very well.